PRINCIPAL COMPONENTS: PETROLOGY AND CHEMISTRY OF POLYPHASE UNITS IN CHONDRITIC POROUS INTERPLANETARY DUST PARTICLES. Frans J.M. Rietmeijer, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 97131, USA.

Chondritic porous (CP) interplanetary dust particles (IDPs) can be described as 'cosmic sediments'. It should be possible to recognise in these IDPs the 4,500 Myrs old solar nebula dusts. The studies of unaltered chondritic IDPs show that their matrices are a mixture of three different *principal components* (PCs) that also describe variable C/Si ratios of chondritic IDPs [1,2]. Among others, PCs include *polyphase units* (PUs) that are amorphous to holocrystalline, both ultrafine- and coarse-grained, ferromagnesiosilica(te) materials with minor Al and Ca. I accept GEMS [3] as a subset of PUs implying that PUs have variable S/Si ratios. The properties of PCs and their alteration products define the physical and chemical processes that produced and altered these components. PCs are also cornerstones of IDP classification. For example, the bulk composition of ultrafine-grained PCs can be reconstructed using the 'butterfly method' and also allows an evaluation of the metamorphic signatures, *e.g.* dynamic pyrometamorphism, in chondritic IDPs [4,5].

Coarse-grained PUs. I present AEM data on coarse-grained PUs in CP IDP L2011A9. They form two size populations with mean diameters of 533 nm and 1138 nm. One kidney shaped PU, 'Big Guy', is 3.0 x 1.0 µm. The majority of Mg,Fe-olivines and pyroxenes, and "restite" grains in PUs ranges from ~10 nm to 410 nm in size, with larger grains up to 790x155 nm. The "restite" grains are amorphous aluminosilica materials with compositions in the 'mullite' field of the $CaO-Al_2O_3-SiO_2$ phase diagram. These phases in the smaller PUs are randomly distributed. The PUs are sulfur free but they are intimately associated with very low-Ni pyrrhotite grains (~110 nm in size). The constituents in the smaller PUs and associated sulfides have equilibrium grain boundaries. The larger PUs have an 'open' texture of disconnected grains.

CHEMISTRY. The compositions of IDP constituents are presented in the ternary diagram Mg-Fe-Si (el wt%) wherein the average compositions of the smaller PUs cluster on the 'pyroxene' line. This average represents two populations with averages on the 'smectite' and 'serpentine' lines in the diagram [NOTE: the materials are smectite and serpentine dehydroxylates rather than layer silicates, *cf*. ref. 5]. The "restite' phase occupies the Si-corner. A line from this corner through the average ferromagnesiosilica compositions, with the most ferromagnesiosilica materials having olivine compositions, intersects the Mg,Fe-join of the diagram at Fe/(Fe+Mg) = 0.23; this is the 'PU-line'. The compositions of olivine and pyroxene crystals are at the intersections of the 'PU-line' and 'olivine' and pyroxene' lines. The average compositions of the larger PUs plot at the intersections of the 'smectite' line and their 'PU-lines' that intersect the Mg,Fe-join between Fe/(Fe+Mg) = 0.07-0.33 but mostly at 0.25. Calcium in PUs is associated with materials of 'smectite' composition, or with Ca-rich clinopyroxenes [5]. The PU 'Big Guy' in L2011A9 consists of a homogeneous ferromagnesiosilica (crystalline) and *ibid* aluminiosilica (amorphous) fraction. Its bulk composition and its constitent phases define a 'PU line' that intersects the Mg,Fe-join at Fe/(Fe+Mg) = 0.32.

Ultrafine-grained PUs. In CP IDP L2011K7 the average compositions of these sulfur-free units define a trend along the 'serpentine' line with $Fe^{2+}/(Mg+Fe^{2+})$ between 0.3 and 0.7 [4]. They have ultrafine-grained Fe,Mg-olivine and pyroxene, and Fe,Ni-oxides and metal in an amorphous ferromagnesiosilica matrix [5]. Similar PUs in L2011A9 typically contain sulfur in disc-shaped pyrrhotites (< 50 nm). Their bulk Fe/Si (at) ratios are similar to those of larger Fe,Ni-sulfides in this IDP although lower Fe/Si ratios are common. They occur in two groups with (i) an average composition on the 'serpentine' line at Fe/(Fe+Mg) = 0.44, and (ii) a group average on the 'pyroxene' line whereby a line from the Si-corner of the diagram through this composition intersects the Mg,Fe-join at Fe/(Fe+Mg) = 0.82. This line delineates the most Fe-rich ferromagnesiosilica compositions in IDPs [4,5].

Discussion. In the diagram Mg-Fe-Si (el. wt%), the PUs define two trends, *viz*. (1) coarse-grained PUs on 'PU-lines' that originate in the Si-corner and connect all phase compositions within a PU to intersect the Mg,Fe-join between Fe/(Fe+Mg) = 0.07-0.33, and (2) ultrafine-grained PUs along the 'serpentine' line which terminates at one end on the 'PU-lines'. A simple interpretation of these distinct trends assumes different reservoirs for the units. The variable sulfur contents of the ultrafine-grained PUs may be related to atmospheric entry heating. It is also likely that the range in intersection points of the 'PU-lines' reflects Mg-loss during entry although the olivine compositions only support noticeable Mg-loss in 'Big Guy'.

The 'PU-lines' for coarse-grained and 'butterflies' for the ultrafine-grained PUs show that closed-system (Si,Al)/(Mg,Fe) fractionation was a common feature during chondritic IDP evolution [4]. I note that the ternary diagram only describes silicate phases but not Fe,Ni-phases (sulfides, oxides, metals, and carbides) in chondritic IDPs which can be introduced as mixing lines from the Fe-apex of the diagram to silicate compositions.

The line delineating the most Fe-rich compositions in IDPs coincides with the maximum $Fe^{2+}/(Mg+Fe^{2+})$ ratios in olivine and pyroxene under fO_2 conditions at the stability of Fe^0 [6]. Metallic iron in PUs may originally have been present due to aging of Si_2O_3 condensates [7], *i.e.* $Si_2O_3 + FeO = 2SiO_2 + Fe^0$. During subsequent sulfidation, *e.g.* $Fe^0 + H_2S = FeS + H_2$, the Fe-metal inclusions in the amorphous ferromagnesiosilica matrix reacted to disc-shaped pyrrhotites. At higher fO_2 fugacities [6] the layer silicate dehydroxylates in PUs equilibrated at ~1700°C and followed by kinetically controlled olivine and pyroxene formation as a function of heating rate [5]. This admittedly complex sequence of events explains the remarkable co-occurrence of olivines, pyroxenes and Fe(Ni)-sulfides with equilibrium grain boundaries seen in GUs. Pyrrhotites in anhydrous IDPs are believed to be a nebular condensate phase [8] but the above scenario implies that at least in L20011A9 and -K7 a fraction of these sulfides formed *in situ* highlighting another aspect of early solar nebula dusts.

PCs. Several investigators have commented on the fact that PCs, including GEMS, do not have a chondritic composition although a particular element in different PCs may occur with CI abundances. In fact, the major element/Si ratios normalised to CI in CP IDPs are between zero and unity; only Mg/Si ratios show a mode slightly less than the CI value [9]. The major element abundances in Table 1 show that chondritic IDPs are only one type of solar nebula dust. In order to acquire CI abundances for Ca, Al, Fe, Ni, and S at least two additional dust types are required, *e.g.* Fe,Ni-sulfides, Ca-rich clinopyroxenes, and Ca,Al-rich [10] particles. These probably micron-sized dusts were observed in chondritic IDPs and occur as individual particles in the NASA/JSC Cosmic Dust Collection, underscoring the importance of cluster IDPs [11].

Table 1: Major element(excl. C)/Si abundances normalised to CI in ultrafine (Ufg)-, incl. GEMS, and coarse (Cg)-grained PUs, and two other solar nebula dusts in chondritic IDPs. X: close to and [X] well below the CI value.

	Ufg-PUs	Cg Pus	"1"	"2"
Mg	X	[X]		
Al	[X]	[X]	X	
Ca	-	[X]	X	
Fe	[X]	[X]		X
Mn	-	[X]		
Ni	[X]	-		X
S	[X]			X

CONCLUSIONS. The nonchondritic PCs of chondritic IDPs include amorphous ferromagnesio-silica units. These polyphase units are S-rich ultrafine-grained PUs and S-free coarse-grained PUs from different dust reservoirs. The corollary of these observations is that chondritic cluster IDPs consist of Fe,Ni-sulfides and refractory dust in addition to nonchondritic Pcs.

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